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Polarization State Transformation of Laser Beam Passing Through Quartz Crystals

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Abstract

Periodical changing of laser beam polarization with initial polarization of 45°to the optical axis of quartz after its passing through quartz cube depends on crystallographic direction and turn angle of the cube. The resulting polarization is different for quartz with impurity of Co and without any impurity especially for direction parallel to the optical axis. Some peculiarities in the modulation pictures take place at initial polarization of laser beam + 45° or -45° to the optical axis of quartz. It is supposed that observed features in polarization of laser beam can be connected with anisotropy of crystal.

1. Introduction

Light polarization is very intricate area in optics. Polarization appearances are not quite the same for coherent and incoherent sources of light. It is known that many crystals change polarization of light, which passes through them. The study of these changing even for incoherent sources of light is very complicated problem. The use of lasers results in obtaining new information about interaction radiation and matter. We believe that the investigations of the state of polarization of laser beam after its passing through quartz single crystals are very interesting and useful not only for creation different optical devices but for obtaining new data about properties of crystals and coherent radiation.

According to Stocks [1] there are six basic states of polarization: horizontal linear polarization and vertical linear polarization, linear polarization under $\pm$ 45° and at last two kinds of elliptical polarization, right and left.. The polarization under angles $\pm$45°to the optical axis is worthy the especial interest as far as it gives possibility to get almost 100% modulation of the laser beam intensity after its passing through the crystal and in dependence on the turn angle of the sample [2-4].

2. Experimental

The aim of the present work is to obtain the influence of Co impurity in quartz on the polarization of the laser beam passing through the quartz cube under various angles. The polarization of laser beam after passing through the crystal depends also on the initial polarization of laser beam ($\pm$45°) [1] that falls onto the sample and presence of impurity. Two kinds of quartz were measured: colorless quartz without impurity and slightly blue quartz with impurity of Co. The samples were prepared in form of cubes with high accuracy. One of the edges of cube was parallel to the optical axis of quartz. All measured single crystals were quite transparent and had high quality.

In our experiment the narrow laser beam was directed to the center of the quartz cube facet. The cube was placed between crossed polarizers on the table of goniometer. The sample can be rotated clockwise, counterclockwise, and also from position of normal incidence cloclwise (conditionally negative angles) and then counterclockwise (conditionally positive angles). The turn angle was measured with 5″ precision.

He-Ne was used as a source of light. The Bruster window of the laser tube was turned so that the laser beam was polarized under angle 45° to the optical axis of quartz.

3. Results and Discussion

It was obtained that the modulation of the laser beam intensity is connected with changing of the state polarization of light and takes place upon the sample rotation. During one period the polarization transforms from one linear polarization, for example -45°, to another linear polarization, +45°, passing through all forms of the elliptical polarization. Period of modulation depends on such factors as crystallographic direction, presence of impurity and initial polarization of laser beam.

The intensity modulation of laser beam after its passing through the cube made from colorless quartz in direction parallel to the optical axis at normal falling of the beam onto the cube face is shown in Fig. 1-a).
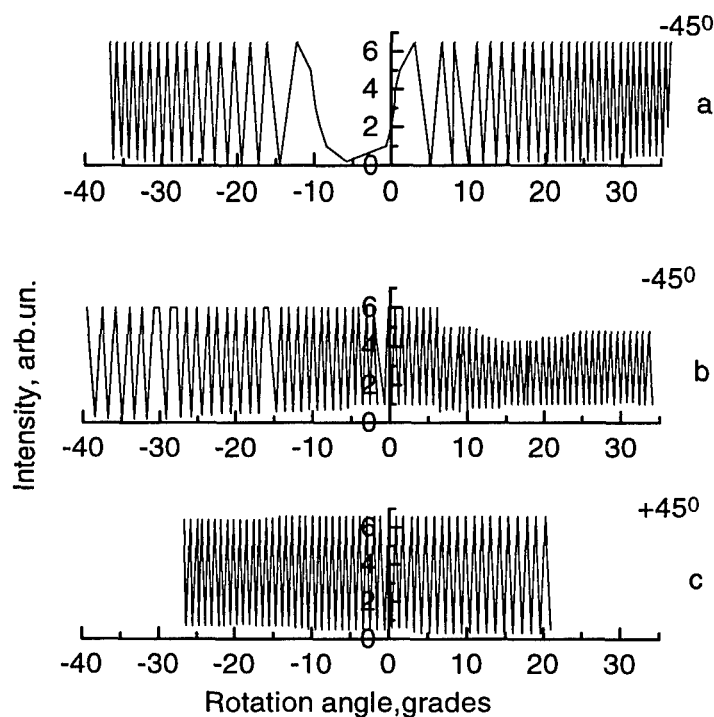

Fig. 1 Modulation pictures for laser beam passing normally to the optical axis for two kinds of quartz: a) Colorless quartz without impurity; b) and c) Belongs to two different samples with the same sizes which made from one piece of blue quartz with impurity of Co. Fig. 1-b) and 1-c) belong also to two different states of polarization of laser beam.

As one can see from the figure that the modulation period decreases to the side of the greater angles of falling and its minimum is equal ~ 50″, and its maximum value is equal ~ 3° without central part. The central part consists of two maximums with elliptical polarization and minimum between them with period ~ 15°. The polarization of next maximums and minimums corresponds to the linear polarization -45° and +45° accordingly.

The modulation period for blue quartz is changed in another way than for colorless quartz. The central part of each picture is wholly occupied with the small period (40 - 45″) maximums. One can say that central minimum with large period is absent for blue quartz. That is the difference between the modulation pictures for colorless quartz and blue quartz with impurity of Co. We would like to notice that transformation of the one linear polarization to another orthogonal one which is accompanied by the turn of electrical vector at 90°, takes place at the turn angle of the sample ~20-25″ when the period of modulation is equal to 40 -50″.
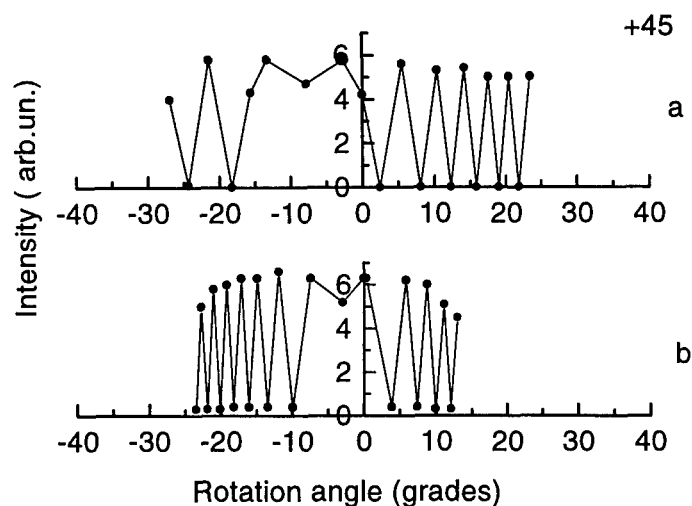
Fig. 2 The intensity modulation of laser beam after its passing through the two different pairs of parallel facets of cube made from blue quartz in direction perpendicular to the optical axis of quartz.

Fig. 1-b) and Fig. 1-c) differ with the different initial polarization of the laser beam what is falling onto the facet of crystal. The period of the intensity modulation decreases from conditionally negative angles towards the conditionally positive angles for the case depicted on Fig. 1-b) from $1,5°$ to $\sim 30''$. The same period increases from conditionally negative angles to conditionally positive ones for the second case with another initial polarization, Fig. 1-c).
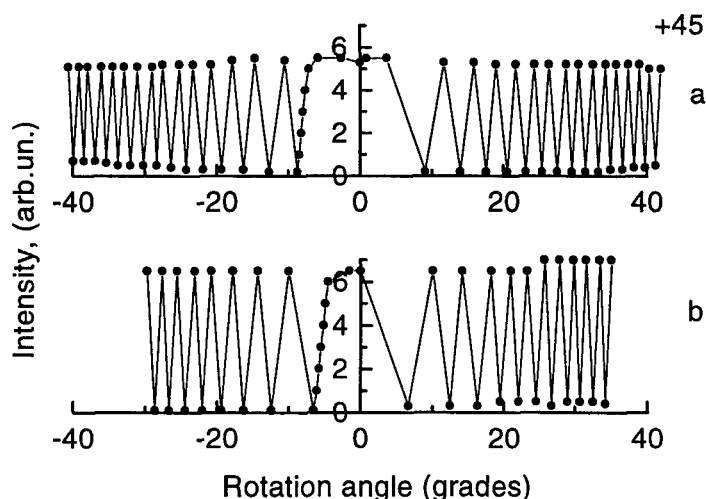
Fig. 3 The intensity modulation of laser beam after its passing through the two different pairs of parallel facets of cube made from colorless quartz in direction perpendicular to the optical axis of quartz.

Such modulation of intensity cannot be observed when the electrical vector of laser beam was parallel or perpendicular to the optical axis of quartz. It cannot be observed too when other non-laser sources of light are used, for example, mercury lamp.

As it is shown in Fig. 2 there is some difference between the two modulation pictures when laser beam passing in directions perpendicular to the optical axis for blue quartz. Here we can see central maximum with large period which is absent for the direction parallel to the optical axis for this sample and for this polarization shown in Fig. 1-c).

The difference between the two modulation pictures for the directions perpendicular to the optical axis is greater for blue quartz in comparison with colorless quartz for the same initial polarization. We believe that this difference is connected with anisotropy in atoms' location in lattice of quartz.

There is some difference between the modulation pictures obtained for some pair of parallel facets of one and the same sample but for different polarization of laser beam falling onto the facet of the cube. It can be difference in period of modulation, in the position of central part of the picture and in the intensity of radiation.
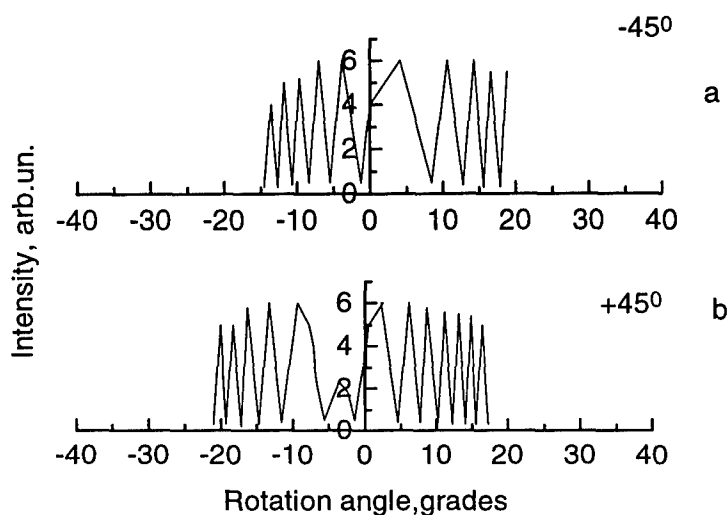

Fig. 4 The intensity modulation of laser beam after its passing through the cube made from blue quartz with impurity of Co in direction perpendicular to the optical axis for one and the same pair of facets but for different polarization of the falling beam.

4. Conclusions

Partly the picture of intensity modulation can be explained with interaction of the two orthogonal polarized waves, ordinary and extraordinary ones, which go the same way with different rates and amplitudes. This interaction depends on such parameters as birefringence, optical activity and the optical length of the light way. But it can be supposed that the main role in transformation of polarization of laser beam plays the features of structure of the measured crystals.

References

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